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INTERNATIONAL APPLICATION

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| NO: | PCT/CA2003/002031 |
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| TITLE: | EXTERNAL COMBUSTION ROTARY PISTON ENGINE |
| APPLICANT: | REVOLUTION ENGINE CORPORATION et al. |
| RESPONSE TO: | FIRST WRITTEN OPINION |
| EXAMINER: | Lequeux, F. |
| OUR FILE: | 42370-0002 |

February 24, 2005

International Preliminary
Examining Authority
European Patent Office
P.B. 5818 Patentlaan 2
NL-2280 HV Rijswijk –Pays Bas

**BY FACSIMILE + 31 70 340 3016**
**AND REGISTERED MAIL**

Dear Sirs:

This response is filed pursuant to Rule 66.3 PCT.

Pursuant to Rules 66.1(b) PCT, Rule 66.3 PCT and Article 34 PCT, the Applicant requests that pages 2-3 and 26-31 the present application be removed and that amended pages bearing numbers 2-3 and 26-30, enclosed herewith pursuant to Rule 66.8(a) PCT, be substituted therefor. In the amended pages, the Applicants have entered a description of reference D1; added references to the claims; and changed a reference to the expression "power transfer means" in claim 11 to read "shaft", to provide suitable antecedent basis; and removed the words "such that less work is required to produce the pressurized air".

**REMARKS**

Responsive to paragraph 1(a) of the First Written Opinion, the Applicants deny the expression "power transfer means" lacks clarity. The expression is a statement of function, which is permitted under III-2.1 of the *Guidelines*, provided that a skilled man would have no difficulty in providing some means of performing this function without exercising inventive skill or that such means are fully disclosed in the application. In this case, both factors apply. Any person of ordinary skill would readily understand that various mechanisms could be used to transfer power from a motor and a gas expander to a compressor and a load. A shaft is also specifically disclosed in the application. Other alternatives could include chain drives or belt drives. Withdrawal of the objection to "power transfer means" is respectfully requested.

Responsive to paragraph 1(b) of the First Written Opinion, the applicants further deny any lack of clarity in the expressions "expanding substantially adiabatically", "the combuster means is adapted to receive varying amount .. of power in use" and "the compressor is adapted.. to the load being driven by the power". These expressions do not represent attempts to define the subject-matter in terms of the result to be achieved, they merely define various of the elements of the inventive engine in terms of the functions which they perform. As indicated earlier, statements of function <u>are</u> permitted in the claims, and in this case, specific examples are provided. Withdrawal of the objection in this regard is respectfully requested.

Responsive to paragraph 1(c) of the First Written Opinion, the Applicant submit that persons of ordinary skill in the art would readily perceive "a reservoir" to refer to a storage container for fluids that typically permits only unidirectional flow. This is in contrast to a pressure tank, wherein flow enters through a passage, and then exits in reverse direction through the same passage. This is also in contrast to a conduit, which is intended for permitting passage of fluids, and serves the store the fluids only incidentally. Withdrawal of the objection to the expression "reservoir" is respectfully requested.

Responsive to paragraph 1(d) of the First Written Opinion, the Applicants respectfully deny that the disclosure suggests any limitation to the types of machines contemplated by the inventor. Indeed, page 24, lines 7-11, clearly contemplates other types of mechanisms

> "... As well, other non-rotary configurations of the engine are possible. By way of example, a first compression could be accomplished with a piston, with the air being piped to another location for secondary compression using a rotor. Similarly, the expansion can be multi-staged, employ different means from one stage to the next, with the various stages taking place in different locations..."

Yet further configurations are possible. For example, if the engine were driving a generator, an electric motor could drive the compressor. In this case, the conductor would form part of the power transfer means.

In paragraph 1(e) of the First Written Opinion, the Examiner indicates that it is not clear how a radiator that cools the compressed air discharged by a compressor can reduce the work required by the compressor to compress this air. The Applicants have recast claim 1, for the purpose of clarification. By way of explanation, it is noted that the compressor herein is adapted to release air from its air chamber during compression: that is, the air chamber is in communication with the interior of the radiator during compression. Thus, the work associated with the compression is directly related to the pressure of the gas in the radiator. If the gas contained in the reservoir is cooled, its pressure decreases, thereby reducing the amount of work that must be performed in the compression step.

In response to paragraph 1(f) of the First Written Opinion, in the claimed invention, the combustion process is internal to the work fluid, in contrast to a simple steam engine where the combustion occurs outside the boiler. For this reason, the present invention can and should be considered an internal combustion engine. Reinstatement of the original title is respectfully requested.

In paragraph 2, the Examiner indicated that claim 1 lacks novelty in view of reference D1. This reference shows an external boiler 20 which absorbs some of the heat of combustion via a heat exchange means 6a. This heat boils the water in 20 to create pressurized steam which is introduced to the drive rotors. This arrangement, wherein heat is extracted from the gases <u>after</u> combustion, is in <u>direct</u> contrast with the claimed invention, wherein heat is extracted from the gases <u>before</u> combustion.

To restate, reference D1 fails to teach a radiator adapted to receive pressurized air from the compressor, and thus, fails to obtain the benefits associated with this structure, namely, reduced workload on the compressor, and reduced NOx production flowing from the reduced peak combustion temperature. Accordingly, the Examiner is respectfully requested to reconsider and withdraw the lack of novelty objection based on D1.

As the Examiner has failed to identify with particularity teachings in the prior art which are alleged to teach or suggest the substance of claims 2-10 and 12-13, the applicant respectfully declines to respond to the allegation of lack of novelty and/or inventive step made in paragraph 2 of the First Written Opinion.

Claims 14-20 have been deleted, such that no response to paragraphs 5,6 is called for.

With regard to the allegation that claims 1,11 and 14 lack conciseness, the Applicants rely on paragraph III-3.2 of the *Guidelines*, wherein it is stated that the presence of different claims may assist the Applicant in later obtaining full protection for his invention, such that the Examiner should not adopt an overly rigid approach to the presence of a number of claims of similar effect.

The Applicants respectfully decline the invitation to recast the independent claims in the two-part form. The Applicants have followed the suggestion of the Examiner to enumerate the claims. The Applicants have further followed the suggestion of the Examiner to insert a commentary on the D1 reference. A commentary on D2 did not appear appropriate, in view of the deletion of claims 14-20, and thus, no such commentary has been entered.

In view of the foregoing amendments and remarks, further prosecution and establishment of a favorable International Preliminary Examination Report is earnestly and respectfully requested.

Pursuant to Rule 66.4(b) PCT, the Applicants respectfully request that they be given one or more additional opportunities to submit amendments and/or arguments, should the amendments and/or arguments presented herein be deemed insufficient to overcome all objections raised by the International Preliminary Examining Authority.

Respectfully submitted

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<u>Enclosures</u>
Substitute disclosure pages 2,3
Substitute claim sheets 26-30

30 degrees from TDC or after 135 from TDC, so a considerable amount of efficiency is lost.

A yet further problem common to this type of engine is that the high combustion temperatures under which this engine operates result in relatively high NOx emissions.

In United States Patent No. 6530211 (Holtzapple et al.), issued March 11, 2003, an engine is disclosed which comprises a compressor for ambient air, a combuster and an expander. The combuster receives fuel and burns same with the compressed air to produce exhaust gases. The expander receives the exhaust gases and expands them. The compressor may be a gerotor compressor or a piston compressor having variable-dead-volume control. The expander may be a gerotor expander or a piston expander having variable-dead-volume control. The combuster may be a tubular combuster. The gases exiting the expander are hot; some of the heat from such gases is removed by passage through a heat exchanger, which transfers the heat to the gases entering the combuster. The variable dead volume device consists of a piston in a cylinder. The position of the cylinder in the piston is set by an actuator, such as an electric servo motor. When the piston is moved to provide a small dead volume, the gases can reach high pressures. In contrast, when a large dead volume is provided, gas pressures remain low. Regulating the compression ratio in this manner allows the power output of the engine to be adjusted. As well, the gerotor configuration of this engine overcomes in part, the vibration and wear issues associated with piston-cylinder engines. However, the gerotors are difficult to fabricate. Further, the servos add complexity to the design, with attendance maintenance issues.

In United States Patent No. 5101782 (Yang), issued April 7, 1992, a rotary piston engine is disclosed. This engine includes two segregated compression and expansion chambers and one separate combustion chamber. In the compression and expansion chambers, a pair of screw-shaped rotors are mounted. In operation, the rotors in the compression chamber compress air. The compressed air is introduced, with fuel, to the combustion chamber, which is then closed, and the contents ignited, such that the fuel burns in a constant volume. The high pressure combustion products are then ported to the

expansion chamber, which causes the rotation of a further pair of screw-shaped rotors, and the combustion products are cooled and exhausted. A portion of the heat removed from the combustion products is the same heat added to the compressed air. This engine is indicated by its inventor to be characterized by high efficiency, high reliability and quiet operation. However, the need to employ screw-shaped rotors adds to cost, and the engine is prone to the production of high NOx emissions, resultant from the high temperatures employed.

## DISCLOSURE OF THE INVENTION

It is an object of the present invention to provide an engine which is relatively simple to fabricate, which is relatively efficient and reliable in operation and which produces relatively low NOx emissions. This object, amongst others, is met by the present invention, an engine for use with a load.

According to one aspect, the engine comprises a compressor, combuster means, a positive displacement air motor, a positive displacement gas expander and power transfer means.

The compressor is adapted to receive power and, upon receiving power, to: periodically define a chamber; fill the chamber with ambient air; and carry out a pressurization process wherein the chamber volume is decreased to produce pressurized air.

The combuster means is for receiving fuel and combusting same in a combustion process with the pressurized air to produce primary exhaust products.

The air motor is adapted to be driven by the primary exhaust products to produce power and secondary exhaust products.

The gas expander is for receiving the secondary exhaust products and expanding same substantially adiabatically to produce tertiary exhaust products and power.

The power transfer means is for directing power produced by the air motor and the gas expander in use to drive the compressor and the load.

The combuster means is adapted to receive varying amounts of fuel, thereby to cause the power transfer means to drive the load with varying amounts of power in use.

CLAIMS

1. An engine for use with a load, said engine comprising:

a compressor adapted to receive power and, upon receiving power, to: periodically define a chamber; fill the chamber with ambient air; and carry out a pressurization process wherein the chamber volume is decreased to produce pressurized air,

a radiator adapted to receive pressurized air from the compressor and upon receiving pressurized air, to cool it such that less work is required to produce the pressurized air,

combuster means for receiving fuel and combusting same in a combustion process with the pressurized air to produce primary exhaust products,

a positive displacement air motor adapted to be driven by the primary exhaust products to produce power and secondary exhaust products,

a positive displacement gas expander for receiving the secondary exhaust products and expanding same substantially adiabatically to produce tertiary exhaust products and power, and

power transfer means for directing power produced by the air motor and the gas expander in use to drive the compressor and the load,

wherein:

the combuster means is adapted to receive varying amounts of fuel, thereby to cause the power transfer means to drive the load with varying amounts of power in use; and

the compressor is adapted to, during the pressurization process, release air from the chamber for said combustion in a manner such that the pressure in the chamber during the pressurization process and the pressure of the primary exhaust products driving the air motor is at a substantially constant level at steady state conditions, said level adjusting spontaneously to the load being driven by the power.

2. An engine according to claim 1, wherein the compressor is a rotary compressor.

3. An engine according to claim 1, wherein the combuster means comprises a tubular combuster.

4. An engine according to claim 1, wherein the air motor is a rotary air motor.

5. An engine according to claim 1, wherein the gas expander is a rotary gas expander.

6. An engine according to claim 1, wherein the power transfer means comprises a shaft operatively coupled to each of the compressor, the air motor and the gas expander.

7. An engine according to claim 1, further comprising a reservoir adapted to receive pressurized air from the compressor and wherein the combuster means receives air for said combustion from the reservoir.

8. An engine according to claim 1, wherein the radiator also serves as a reservoir adapted to receive pressurized air from the compressor and wherein the combuster means receives air for said combustion from the radiator.

9. An engine according to claim 2, wherein the radiator also serves as a reservoir adapted to receive pressurized air from the compressor and wherein the combuster means receives air for said combustion from the radiator.

10. An engine according to claim 1, wherein the expansion ratio defined by the expander is larger than the compression ratio defined by the compressor.

11. An internal combustion engine for use with a load, said engine comprising:

a rotary compressor adapted to receive power and, upon receiving power, to: periodically define a chamber; fill the chamber with ambient air; and carry out a pressurization process wherein the chamber volume is decreased to produce pressurized air,

a radiator coupled to the compressor to receive the pressurized air and adapted to cool said pressurized air and to function as a reservoir therefor,

a first backflow preventer and a second backflow preventer, each coupled to the radiator to permit unidirectional flow therefrom;

a pressure tank coupled to the first backflow preventer to receive pressurized air from the radiator;

a valve coupled to the pressure tank to permit the selective release of pressurized air from the pressure tank;

a tubular combuster coupled to the valve and to the second backflow preventer to receive pressurized air from the radiator and pressurized air selectively released from the pressure tank and adapted to receive fuel and combust same in a combustion process with the pressurized air so received to produce primary exhaust products,

a positive displacement rotary air motor coupled to the combuster so as to be driven by the primary exhaust products to produce power and secondary exhaust products,

a positive displacement rotary gas expander coupled to the air motor for receiving the secondary exhaust products and expanding same substantially adiabatically to produce tertiary exhaust products and power, and

a shaft operatively coupled to each of the compressor, the air motor and the gas expander for directing power produced by the air motor and the gas expander in use to drive the compressor and the load,

wherein:

the combuster means is adapted to receive varying amounts of fuel, thereby to cause the power transfer means to drive the load with varying amounts of power in use; and

the compressor is adapted to, during the pressurization process, release air from the chamber for said combustion in a manner such that the maximum pressure in the chamber during the pressurization process and the pressure of the primary exhaust products driving the air motor is substantially constant at steady state conditions, said constant being a function of the power driving the load.

12. An engine according to claim 1, wherein the expansion ratio defined by the expander is larger than the compression ratio defined by the compressor.

13. An engine according to claim 1, wherein the compressor is a three stage compressor.

14. A device for transferring power between a rotatable shaft and a source of gas, said device comprising:

housing means for defining a pair of fluid ports and a piston chamber in fluid communication with each of the fluid ports,

a multilobe piston mounted in said piston chamber for rotation about a first axis and couplabe in use to said shaft to provide for rotation of one of said piston and said shaft upon rotation of the other; and

a pair of gate rotors mounted in said piston chamber for rotation each about a respective second axis, in sealing contact against said piston and coupled to said piston to provide for rotation of one of said piston and said gate rotors upon rotation of the other, said gate rotors having sockets therein to receive the lobes during said rotation,

the piston and the gate rotors dividing the piston chamber into multiple subchambers of changing volume as the piston and rotors rotate, said subchambers being in communication with the fluid ports in a manner which permits operation of the device: as a compressor upon coupling one of the fluid ports to a source of fluid to be compressed and coupling the piston to a drive shaft; and as an expander upon coupling the one fluid port to a source of fluid to be expanded,

wherein the first axis and the second axes are parallel to one another, and wherein the second axes are 180° apart from one another relative to the first axis.

15. A device according to claim 14, wherein each gate rotor has two sockets located 180° apart from one another relative to the second axis about which said each gate rotor rotates, and wherein the piston has four lobes located 90° apart from one another relative to the first axis

16. A device according to claim 14, in use as the positive displacement gas expander in the engine of claim 12.

17. A device according to claim 14, in use as the positive displacement air motor in the engine of claim 12.

18. A device according to claim 14, in use as the first compression stage in the engine of claim 13.

19. A device according to claim 14, in use as the second compression stage in the engine of claim 13.

20. A device according to claim 14, wherein each gate rotor has four sockets located 90° apart from one another relative to the second axis about which said each gate rotor rotates, and wherein the piston has eight lobes located 45° apart from one another relative to the first axis.